Available online at www.sciencedirect.com

SciVerse ScienceDirect

Physics Procedia 23 (2012) 69 – 72

Physics Procedia

Asian School-Conference on Physics and Technology of Nanostructured Materials (ASCO-NANOMAT 2011)

Development of microwave absorbing materials prepared from a polymer binder including Japanese lacquer and epoxy resin

T. Iwamaru[a,*], H. Katsumata[a], S. Uekusa[a], H. Ooyagi[a], T. Ishimura[b], T. Miyakoshi[a]

[a]Department of Electronics and Bioinformatics, School of Science and Technology, Meiji University, Kawasaki 214-8571, Japan
[b]Kitami Institute of Technology, 165-Banchi, Kouen-Chou, Kitami-Si, Hokai-Do 090-8507, Japan

Abstract

Microwave absorption composites were synthesized from a poly urushiol epoxy resin (PUE) mixed with one of microwave absorbing materials; Ni-Zn ferrite, Soot, Black lead, and carbon nano tube (CNT) to investigate their microwave absorption properties. PUE binders were specially made from Japanese lacquer and epoxy resin, where Japanese lacquer has been traditionally used for bond and paint because it has excellent beauty. Japanese lacquer solidifies with oxygen contained in air's moisture, which has difficulty in making composite, but we improved Japanese lacquer's solidification properties by use of epoxy resin. We made 10 mm thickness composite samples and cut them into toroidal shape to measure permittivity, permeability, and reflection loss in frequencies ranging from 50 Hz to 20 GHz. Electric magnetic absorber's composites synthesized from a PUE binders mixed either with Soot or CNT showed significantly higher wave absorption over -27 dB than the others at frequencies around 18 GHz, although Japanese lacquer itself doesn't affect absorption. This means Japanese lacquer can be used as binder materials for microwave absorbers.

Keywords: wave absorption; microwave; Japanese lacquer

* Corresponding author. Tel.: +81-44-934-7301; fax: +81-44-934-7909.
E-mail address: ce01010@meiji.ac.jp , katumata@meiji.ac.jp.

doi:10.1016/j.phpro.2012.01.018

1. Introduction

Today, many kinds of electromagnetic waves are used in our world around us. Wireless applications such as, wireless local area network, and mobile phones have still increased demands in gigahertz (GHz) range. In the days to come, electromagnetic waves are supposed to be improved to have higher frequencies in GHz, which could result in crosstalk and noise problems that called electromagnetic interference (EMI). Microwave absorbers which can solve EMI problems have been investigated so far [1-3].

In the wave absorbers, dielectric materials are commonly used for binders, which can be used for filler of absorption materials. In many cases, binders are mixed with absorption materials such as ferrite and carbon. Absorption materials have electromagnetic absorption properties with the imaginary part of dielectric loss ($\varepsilon r''$) by e.g. carbon and imaginary part of magnetic loss by e.g. ferrite ($\mu r''$) [4]. Our target is to be over -20 dB loss, which corresponds to 99 % of magnetic wave absorption in 1-20 GHz range.

In this study, we report on the microwave absorption properties of poly urushiol epoxy resin (PUE) binder that would be one of better suited materials for microwave absorber binders. Here, we made a binder from Japanese lacquer and epoxy resin. Japanese lacquer is natural material whose trees grow naturally in East Asia and by scratching the tree bark, we can get the sap. Japanese lacquer liquid has long been used as bond and paint for woodenwares, because it has excellent beauty and can be filled into a lot of inorganic oxide. Recently, Japanese lacquer has attracted attention because it is environmentally-friendly.

By solidification, Japanese lacquer has great resistance properties to chemical agents and water. Japanese lacquer's solidification proceeds through two oxidation processes [5] : auto oxidation, while enzyme oxidation. Auto oxidation occurs with oxygen contained in air's moisture by making alkyl bridge. Enzyme oxidation occurs through catalysis using enzyme contained in low Japanese lacquer in room temperature. Solidifying needs air and certain amount of temperature. Thin film of Japanese lacquer can be touched in large part with oxygen in air's moisture, so Japanese lacquer can become solidify by itself. But solid material of Japanese lacquer doesn't become hard enough because oxygen cannot permeate into the composite. We upgraded Japanese lacquers solidifying properties by adding epoxy resin. Extracted Urushi-ol made from Japanese lacquer and epoxy resin were mixed with a weight ratio of 3:2 and we called the composite samples as PUE with Japanese lacquer. We succeeded in solidification of Japanese lacquer that normally does not solidify by itself.

2. Experiment

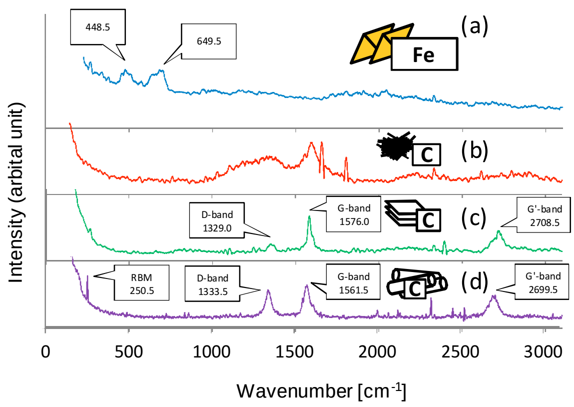
We used the 4 types of powders as microwave absorption materials: Ni-Zn ferrite, soot, black lead, and single wall carbon nanotube (CNT). The crystal structure of these materials is spinnel for Ni-Zn soft ferrite, amorphous carbon for soot, graphite for black lead, and carbon nanotube for CNT.

Urushiol is made of Japanese lacquer that is soluble with acetone. PUE is mixed with urushiol and epoxy resin in which the latter is made of bisphenol A epoxy resin and p-phenylenediamine (p-DP). Finally, microwave absorption composites are prepared by mixing PUE with absorption materials. Epoxy samples can be solidified in a day, while the PUE samples can be solidified in 3 weeks, which indicates that the PUE has slower solidification property. We processed the samples into toroidal shapes after solidification. The samples have outside diameter of 7 mm, inside diameter of 3 mm and thickness of 10 mm.

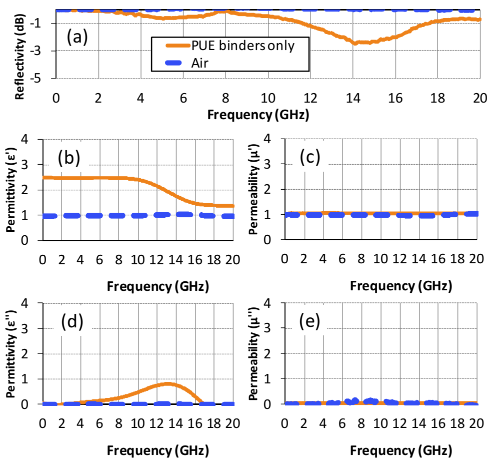
The microwave absorption properties of samples were measured by an Agilent 8722ES vector network analyzer (VNA), where the reflection loss measurement method is adopted and it uses a short-backed cylindrical waveguide sample holder with dimensions of 3.0 mm in inner diameter, 7.0 mm in outer diameter and 10 mm in length. Complex permeability and complex permittivity were extracted in the frequency range from 50 Hz to 20 GHz from S-parameter transmission data using Nicolson-Ross method as important electromagnetic wave absorption parameters [6]. We made totally 12 samples by changing their composition of wave absorption materials in wt%. One of the Ni-Zn Ferrite, Soot, Black lead and CNT powders was mixed with PUE binder during solidifying processes. We defined binder of PUE wt% as being totally equal to 100 wt%. The powder weight ratios of the Ni-Zn Ferrite were 67, 100 and 233 wt%, Soot and Black lead were 5, 10 and 20, CNT were 0.5, 1 and 3wt%, respectively.

3. Results and discussion

Raman spectra of absorption materials are shown in Figs. 1(a)-1(d). It is found from this figure that they exhibits Ni-Zn spinel , amorphous carbon, graphite and CNT structures, where CNT shows radial breathing mode (RBM) peak at 250.5 cm-1. Frequency dependences of absorption properties, reflection loss, complex permeability and complex permittivity for samples with PUE binders only are shown in Figs.2(a)-2(e) together with those for air as a reference. Maximal reflectivity for samples with only PUE binders was shown to be –2.5 dB at 14.1 GHz, which causes loss of imaginary part of permeability.

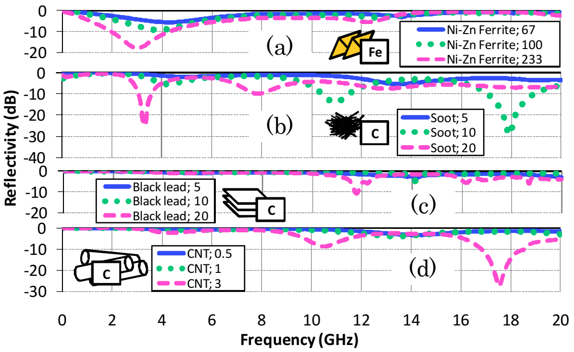


Figs.1(a)-1(d). Raman spectra of (a) Ni-Zn ferrite, (b) Soot, (c) Black lead and (d) CNT



Figs.2(a)-2(e).Frequency characteristics on microwave absorption for samples with PUE binders only and air.

Next, reflection properties for samples with different additional powder weight ratios of absorption materials in PUE binders are compared in Fig.3. Maximal reflectivity was achieved to be -29.0 dB at 17.9 GHz for samples (denoted by Soot;10) added with Soot in PUE binders, which indicates that the reflection loss of this sample was minimized and achieved to a practical level over -20 dB. It is found from Figs. 3(a)-3(d) that the reflectivities for samples added with either Soot or CNT have higher reflection loss, which increase roughly in proportion to absorption material weight, while the peak frequency of reflection loss decreases roughly in proportion to weight. Their higher absorption could be related to crystal defect of Raman D-band as shown in Fig.1. Fig.3(b) demonstrates that the samples mixed with Soot have optimal amount of Soot. From Fig.3, we can say that the reflectivity, permeability and permittivity can be designed from respective samples parameters such as thickness and composition of epoxy and PUE with simulation. Fig.4 shows reflectivity for samples with optimized weights, selected from Fig.3. Carbon materials show higher absorption properties than Ni-Zn ferrite in 10-20 GHz.



Figs.3(a)-3(d).Reflection properties for samples with different absorption materials with different powder weight ratios in PUE binders.

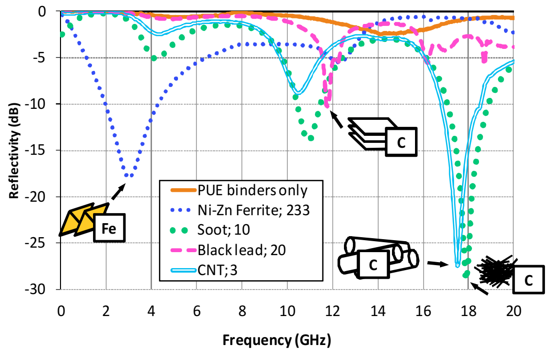


Fig.4.Frequency characteristics on absorption for Epoxy samples with different powder weight ratios of Ni-Zn ferrite, Soot, Black lead and CNT

4. Conclusions

We synthesized PUE binders by mixing Japanese lacquer and epoxy resin and found that the microwave absorption composites prepared from PUE binders mixed with carbon materials showed higher absorption properties than Ni-Zn ferrite in 10-20 GHz. Among carbon materials, PUE binders mixed with either CNT or Soot showed higher absorption properties of -27.4 dB at 17.5 GHz and –29.0 dB at 17.9 GHz than those mixed with Black lead. We assume that it could be caused by crystal defect of Raman D-band. This means that PUE binder made from Japanese lacquer and epoxy resin can be used as electromagnetic wave absorption binders. In the days to come, we are going to try to apply Japanese lacquer to coat some objects such as wall, furniture and electric devices, which needs to develop techniques for depositing Japanese lacquer thin films and measuring their reflection loss properties.

References

[1] Tong G, Wu W, Hua Q, Miao Y, Guan J, Qian H. Enhanced electromagnetic characteristics of carbon nanotubes/carbonyl iron powders complex absorbers in 2–18GHz ranges. *Journal of Alloys and Compounds* 2011;**509**:451-6.

[2] Kim SI, Kim MR, Cho EK, Sohn KY, Park WW. Electromagnetic wave absorption properties of nanocrystalline Fe-based P/M sheets incorporating multi-walled carbon nanotubes. *Metals and Materials International* 2010;**16**:121-3.

[3] Terada M, Itoh M, Liu JR, Machida K. Electromagnetic wave absorption properties of Fe3C/carbon nanocomposites prepared by a CVD method. *Journal of Magnetism and Magnetic Materials* 2009; **321**:1209-5.

[4] Yusoff AN, Abdullah MH, Ahmad SH, Jusoh SF, Mansor AA, Hamid SAA. Electromagnetic and absorption properties of some microwave absorbers. *Journal of Applied Physics* 2002;**92**:876-7.

[5] Honda T, Lu R, Sakai R, Ishimura T, Miyakoshi T. Characterization and comparison of Asian lacquer saps. *Progress in Organic Coatings* 2008;**61**:68-8.

[6] Nicolson AM, Ross GF. Measurement of the Intrinsic Properties of Materials by Time-Domain Techniques. *IEEE Transactions on Instrumentation and Measurement* 1970;**19**:377-6.